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CONSTRUCTION AND OPERATION OF ELECTRIC BROODERS[1]

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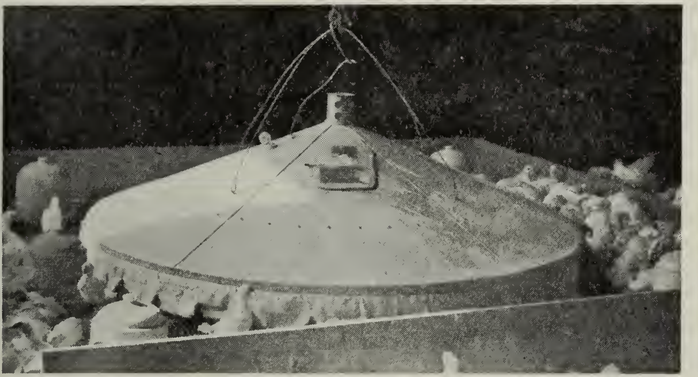

Electric brooder in operation

INTRODUCTION

Electricity is a very desirable source of heat for the artificial brooding of poultry because of its convenience and low fire hazard. It is convenient because it obviates the filling of lamps, trimming of wicks, tending coal heaters, etc., and provides accurate, automatic regulation of temperature. Similar convenience is obtained with gas; but when fire hazard is also considered, the advantage is undoubtedly with electric heat. Electric brooding, however, involves a number of problems which must be understood and given proper consideration if most effective operating results are to be obtained; these problems are discussed in detail in the following pages.

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[1] This publication is the seventh of a series planned to report the results of investigations conducted by the California Agricultural Experiment Station in cooperation with the California Committee on the Relation of Electricity to Agriculture. This circular supersedes Bulletin 441, "The Electric Brooder."

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ELECTRIC BROODING REQUIREMENTS

In artificial brooding, certain essential requirements have to be met. Some of the more important are:

1. Sufficient floor space beneath the brooder to prevent crowding. An allowance of 7 square inches per chick and 14 square inches per turkey poult is recommended because these allowances have been found by experience to give most consistently satisfactory results.
2. Sufficient heating capacity to maintain a temperature of 95 degrees Fahrenheit 2 inches above the floor and 5 inches inside the outer edge of the hover.
3. Heating elements so arranged as to give uniform distribution of heat.
4. Automatic, dependable, temperature regulation.
5. Adequate ventilation.
6. Simplicity of brooder design making for ease of operation and ease of cleaning.
7. Durability of construction.

NON-GLOWING (BLACK HEAT)[4] TYPES OF BROODERS

One of the older types of electric brooder consists of a rather low hover surrounded by curtains and heated by overhead non-glowing heating elements (see fig. 1, and sketch 1, fig. 2). The elements are fastened to the under side of the hover just above the heads of the chicks, and are connected to a thermostatic switch to control the temperature. Ventilation is provided by the natural movement of air in and out of the brooder through the curtain due to the difference in temperature between the air under the hover and that of the room. The rate of ventilation is increased or decreased by raising or lowering the hover.

Sketch 2 (fig. 2) shows a hover employing overhead, non-glowing elements and fitted with a chimney and damper in the apex of the canopy. Since warm air tends to rise, ventilation is established, but there is a rapid loss of heat because the air can pass directly from the heating elements to the ventilator without first circulating through the hover.

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[4] "Black heat" is a term sometimes applied to electric heating elements, which operate at a temperature below the glow point; that is, the wire maintains its natural color (see fig. 18).

Sketch 3 is a further modification of the chimney idea, using a stack which extends down into the brooder, and which may be of one piece or of the telescoping type. The telescoping stack provides a manual adjustment of ventilation. It prevents undue waste of heat. Failure to adjust the stack for changing temperature and moisture conditions, however, may be a source of trouble.

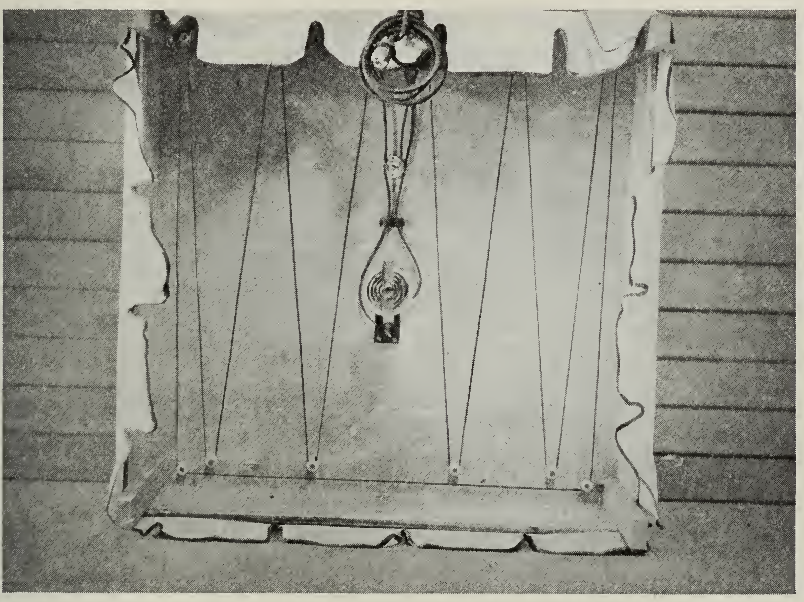

Fig. 1.—A simple, wood, non-glowing electric brooder using overhead heat. Note the use of good electric insulation, an ether wafer thermostatic switch, well designed power leads, and the simplicity of construction. (From Bul. 441.)

Sketch 4 shows the usual hover employing overhead non-glowing elements, with the addition of an air duct in the floor of the brooder. The purpose of this air duct is to permit an upward flow of fresh air through the floor into the brooder. This duct may not bring about satisfactory ventilation unless a heating element is installed as shown in sketch 6.

Sketch 5 shows the usual hover, employing overhead non-glowing elements and equipped with a false floor made of lath covered with burlap. The purpose of this false floor is to prevent floor dampness by means of sub-floor ventilation.

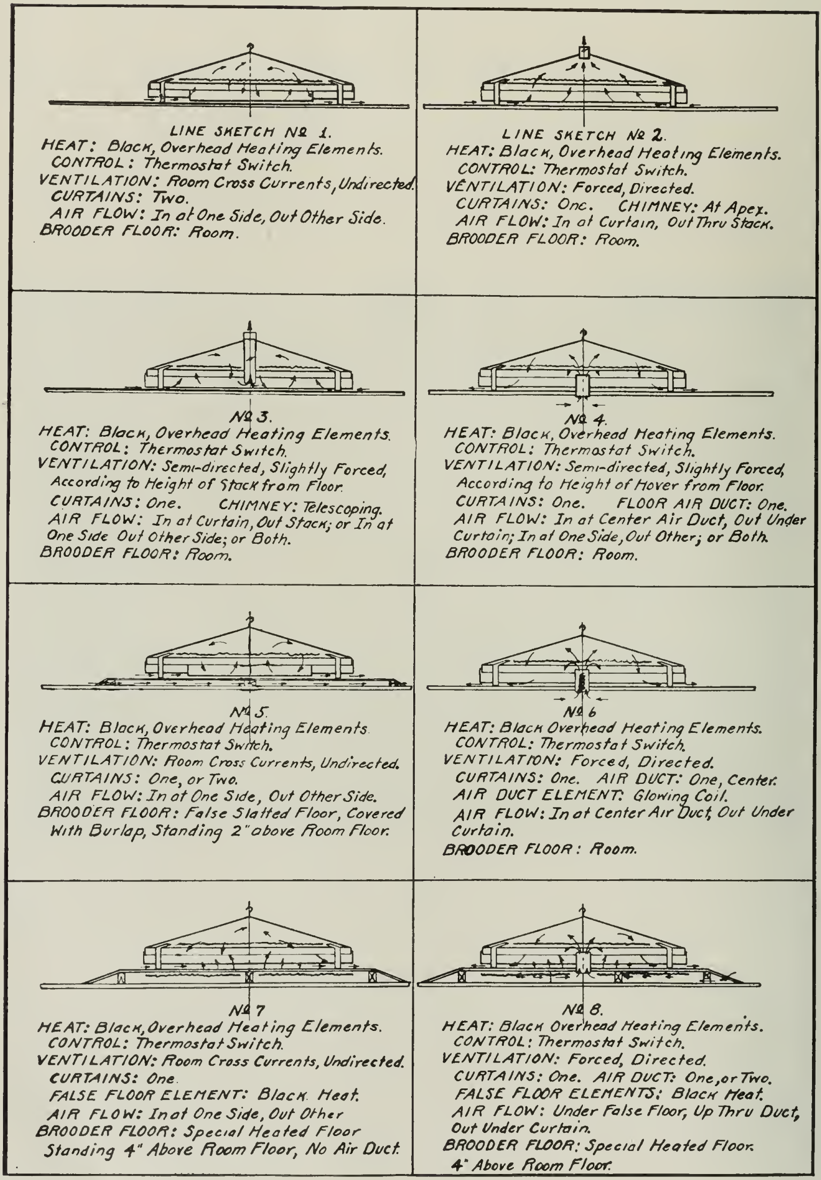
LINE SKETCH Nº 1.
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Room Cross Currents, Undirected.
CURTAINS: Two.
AIR FLOW: In at One Side, Out Other Side.
BROODER FLOOR: Room.
LINE SKETCH Nº 2.
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Forced, Directed.
CURTAINS: One. CHIMNEY: At Apex.
AIR FLOW: In at Curtain, Out Thru Stack.
BROODER FLOOR: Room.
Nº 3.
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Semi-directed, Slightly Forced, According to Height of Stack from Floor.
CURTAINS: One. CHIMNEY: Telescoping.
AIR FLOW: In at Curtain, Out Stack; or In at One Side Out Other Side; or Both.
BROODER FLOOR: Room.
Nº 4.
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Semi-directed, Slightly Forced, According to Height of Hover from Floor.
CURTAINS: One. FLOOR AIR DUCT: One.
AIR FLOW: In at Center Air Duct, Out Under Curtain; In at One Side, Out Other; or Both.
BROODER FLOOR: Room.
Nº 5.
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Room Cross Currents, Undirected.
CURTAINS: One, or Two.
AIR FLOW: In at One Side, Out Other Side.
BROODER FLOOR: False Slatted Floor, Covered With Burlap, Standing 2" above Room Floor.
Nº 6
HEAT: Black Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Forced, Directed.
CURTAINS: One. AIR DUCT: One, Center.
AIR DUCT ELEMENT: Glowing Coil.
AIR FLOW: In at Center Air Duct, Out Under Curtain.
BROODER FLOOR: Room.
Nº 7
HEAT: Black, Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Room Cross Currents, Undirected.
CURTAINS: One
FALSE FLOOR ELEMENT: Black Heat.
AIR FLOW: In at One Side, Out Other
BROODER FLOOR: Special Heated Floor Standing 4" Above Room Floor, No Air Duct
Nº 8.
HEAT: Black Overhead Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Forced, Directed.
CURTAINS: One. AIR DUCT: One, or Two.
FALSE FLOOR ELEMENTS: Black Heat.
AIR FLOW: Under False Floor, Up Thru Duct, Out Under Curtain.
BROODER FLOOR: Special Heated Floor. 4" Above Room Floor.

Fig. 2.—Line sketches showing different methods which have been employed for heating and ventilating electric brooders. (From Bul. 441.)

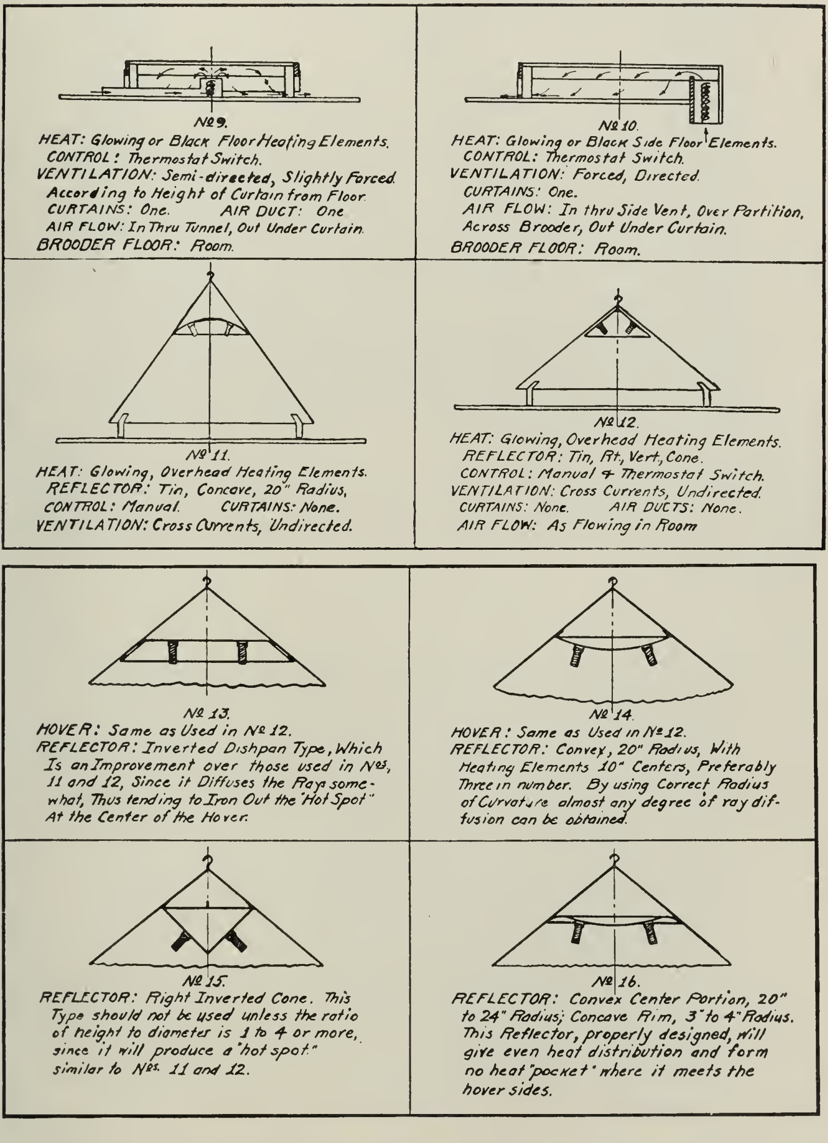
Nº 9.
HEAT: Glowing or Black Floor Heating Elements.
CONTROL: Thermostat Switch.
VENTILATION: Semi-directed, Slightly Forced According to Height of Curtain from Floor.
CURTAINS: One. AIR DUCT: One
AIR FLOW: In Thru Tunnel, Out Under Curtain.
BROODER FLOOR: Room.
Nº 10.
HEAT: Glowing or Black Side Floor Elements.
CONTROL: Thermostat Switch.
VENTILATION: Forced, Directed.
CURTAINS: One.
AIR FLOW: In thru Side Vent, Over Partition, Across Brooder, Out Under Curtain.
BROODER FLOOR: Room.
Nº 11.
HEAT: Glowing, Overhead Heating Elements.
REFLECTOR: Tin, Concave, 20" Radius,
CONTROL: Manual. CURTAINS: None.
VENTILATION: Cross Currents, Undirected.
Nº 12.
HEAT: Glowing, Overhead Heating Elements.
REFLECTOR: Tin, Rt., Vert., Cone.
CONTROL: Manual & Thermostat Switch.
VENTILATION: Cross Currents, Undirected.
CURTAINS: None. AIR DUCTS: None.
AIR FLOW: As Flowing in Room
Nº 13.
HOVER: Same as Used in Nº 12.
REFLECTOR: Inverted Dishpan Type, Which Is an Improvement over those used in Nos. 11 and 12, Since it Diffuses the Rays somewhat, Thus tending to Iron Out the "Hot Spot" At the Center of the Hover.
Nº 14.
HOVER: Same as Used in Nº 12.
REFLECTOR: Convex, 20" Radius, With Heating Elements 10" Centers, Preferably Three in number. By using Correct Radius of Curvature almost any degree of ray diffusion can be obtained.
Nº 15.
REFLECTOR: Right Inverted Cone. This Type should not be used unless the ratio of height to diameter is 1 to 4 or more, since it will produce a "hot spot" similar to Nos. 11 and 12.
Nº 16.
REFLECTOR: Convex Center Portion, 20" to 24" Radius; Concave Rim, 3" to 4" Radius. This Reflector, properly designed, will give even heat distribution and form no heat "pocket" where it meets the hover sides.

Fig. 3.—Continuation of series shown in figure 2. (From Bul. 441.)

Sketch 6 shows a heating element installed in the brooder air duct. During the warm part of the day the overhead heat can be cut off and the air-duct element used to heat the brooder.

Sketch 7 shows a brooder equipped with both overhead heat and a heated floor. The heated floor creates convection currents which tend to increase the air movement within the brooder.

In the brooder shown in sketch 8 circulation of air from beneath the hover floor through a connecting duct to the brooder and then out under the curtains is increased by heating coils in the compartment under the brooder floor. It is important that the inlet to this compartment be somewhat lower than the outlet. As with the brooder shown in sketch 7, some heat is conducted through the floor and sets up additional air currents above.

The type of brooder shown in sketch 9 (fig. 3) consists of a square box which stands about ten inches high, with curtains around the outer edges. The heating elements are centrally located in a cylindrical container which is connected by a duct with the air outside of the brooder. As the air in this central container is heated it moves upward and outward and is replaced by fresh cool air entering through the duct.

Sketch 10 shows a type which consists of a box about 10 inches high, closed on three sides, with a curtain in front. The heating elements are located in a rear chamber which connects with the room from below and with the hover from above. The air enters at the bottom of the heating chamber and passes over a partition into the hover and out through the curtain. The ventilation is very effective owing to the location of the heating elements with respect to circulation.

GLOWING (RADIANT) TYPES OF BROODERS

Some brooders make use of the heat radiated from glowing wires to warm the space occupied by the chicks. They are usually conical in shape with the elements located near the apex. Heat reflectors are used to increase the effect of the heating elements, and some kind of insulating material is applied to the inside surface of the metal of the hover to reduce heat loss to a minimum (figs. 4, 5, 6). Heating elements begin to glow at a wire surface temperature of approximately 800 degrees Fahrenheit (see fig. 18).

The glowing elements used as the heat source in these brooders radiate heat outward in all directions. Since the chicks can be on the underside only, the heat radiated upward would be of no benefit

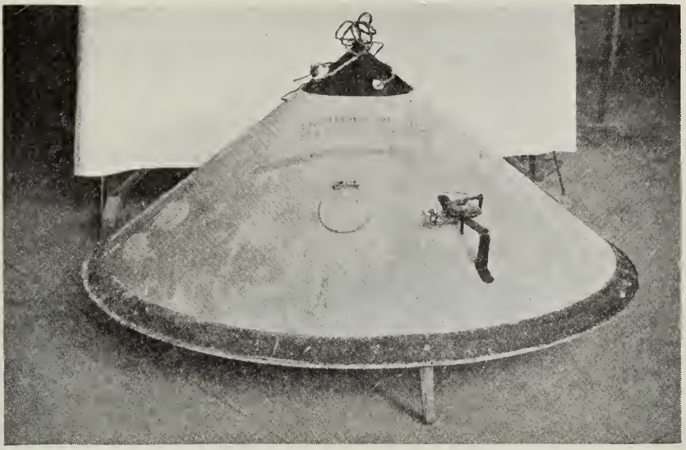

Fig. 4.—A conical, galvanized-iron brooder which uses glowing heating elements and a convex copper heat reflector. Note the short legs, thermostatic switch, observation door on the side, and the heavy bead at the edge which gives the hover rigidity. The brooder height should be about one-half the diameter. (From Bul. 441.)

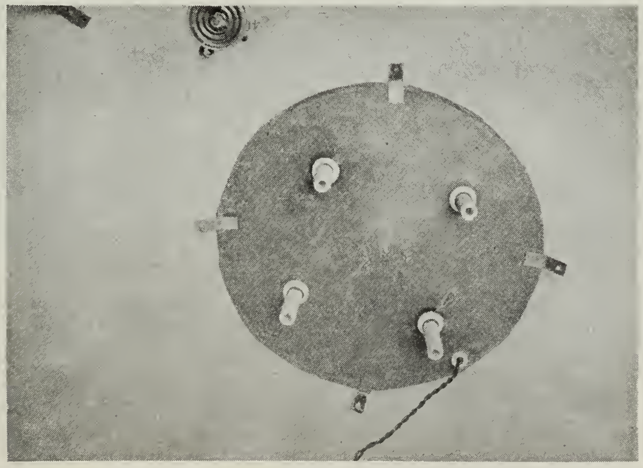

Fig. 5.—A convex copper heat reflector. Two heating elements are on the thermostatic circuit and two are controlled by a hand switch. This type of reflector diffuses the heat, making the complete area under the hover comfortable to the chicks. (From Bul. 441.)

to them if not reflected. The heat reflector, then, plays a very important part in this type of brooder. Concave and cone reflectors (sketches 11 and 12, fig. 3), concentrate the rays toward the center, tending to cause a "hot spot" to be formed on the brooder floor which constitutes waste floor space, since the heat is too intense for the chicks to remain in this area.

This hot-spot condition can be prevented by properly adjusting the height of the reflector from the floor, by using a reflector of correct slope, by lowering the temperature of the wire surface, or by screening the rays. Sketch 13 shows a radiant brooder with a flat reflector which diffuses the rays to some extent. The temperature at the center of the hot spot, due to this diffusion, is slightly decreased and its area increased.

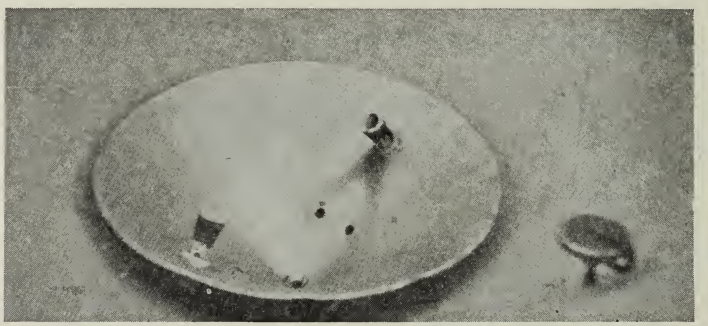

Fig. 6.—A concave cone heat reflector sometimes used in glowing type brooders. It concentrates the heat rays toward the center tending to create a hot spot on the floor. (From Bul. 441.)

Sketch 14 shows a radiant brooder equipped with a convex heat reflector. A convex reflector of small radius diffuses the rays very rapidly, while one of greater radius diffuses to a lesser degree. The radius of curvature should not be less than 20 inches when a hover having a ratio of height to diameter of 1 to 2 is used.

Sketch 15 shows a radiant brooder equipped with an inverted right cone reflector. If this type is used, the height of the reflector or cone should be about one-fifth of its diameter. The resulting diffusion of the rays then approaches that of the convex reflector of large radius as described under sketch 14.

Sketch 16 shows a radiant brooder equipped with a combination convex and concave reflector. The purpose of this design is to obtain as uniform distribution of heat as possible under the brooder and to prevent the formation of uncomfortable hot spots for the chicks.

The reflector and heating units of a radiant brooder should be at least 2 feet above the floor. No harmful effects upon the chicks from the light of glowing elements have been observed.

The reflector should be made of some metal which will not curl or warp when subjected to the heat from the elements. Tinned sheet iron does very well and when it tarnishes can be given a coat of heat-resistant aluminum paint which increases the reflector efficiency. Copper, brass, zinc, or other metals can also be used but galvanized iron is not desirable since the heat causes the zinc coating to peel off.

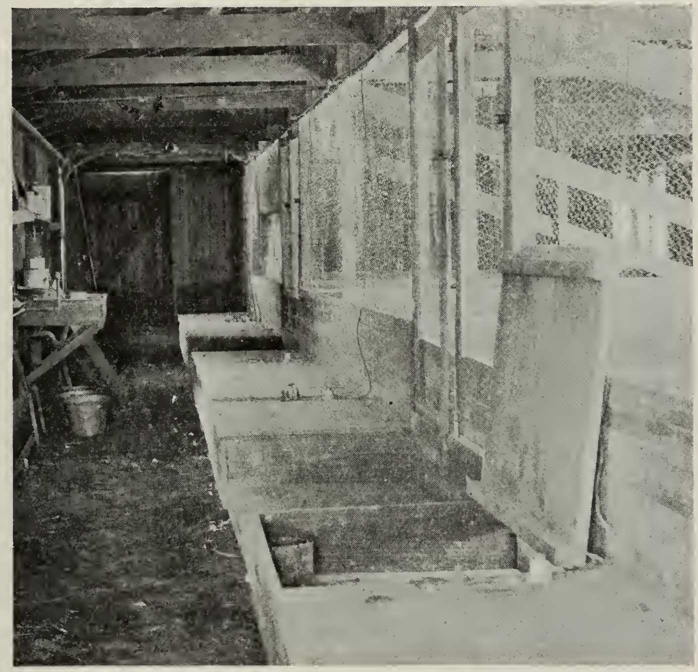

Fig. 7.—An alleyway brooder house with electric brooders built in. The brooders are built in pairs and their construction is shown in sketch 10 of figure 3. The brooders are a foot above the floor of the alleyway so that fresh air can circulate underneath and enter the fresh air intakes extending through the floor of each brooder.

BROODER DESIGN AND CONSTRUCTION

Built-in or Portable Brooders.—In figure 7 is shown a very good type of built-in electric brooder. The hover, as indicated, is all in the alleyway and is constructed as shown in sketch 10, figure 3. The top of a built-in brooder situated in the alleyway will not, because of its location, accumulate a coating of droppings and have to be cleaned at intervals; a brooder that is placed in the room with the chicks requires a top steep enough so that the chickens cannot perch on it.

A portable brooder, however, can be constructed with all of the essential advantages of a built-in brooder, and still retain the advantages resulting from its mobility (see figs. 8, 9). It can be stored away between seasons. It can be entirely removed from one brooder pen, where the chicks no longer need it, to another pen being prepared for a new hatch. Its removal from a brooder room gives unimpeded access to the space it occupied, for the installation of roosts, etc. A special building is not required. It can be used in spare pens, in laying house, or in temporarily available space in a barn or other outbuildings. The factor of portability reduces the investment and adds convenience without necessarily sacrificing any of the real advantages of the built-in type.

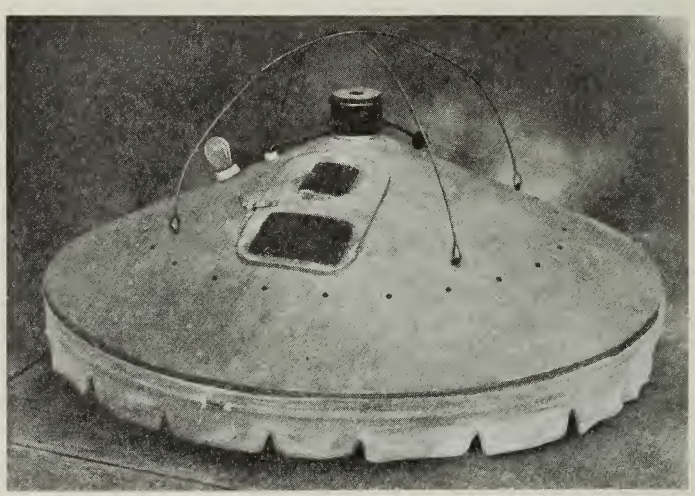

Fig. 8.—Curtained, portable brooder with a very small slope to the top. The interior of this brooder is shown in figure 12.

Curtained or Curtainless Brooders.—A curtain on an electric brooder serves to control ventilation and prevent an undue dissipation of heat (fig. 10).

Electric brooders use the natural system of ventilation whereby the inflow of fresh air and the outflow of stale air are brought about by differences in temperature between the air in the brooder and that in the brooder room. The rate of air flow, however, depends not only on such temperature differences but also on the size and location of the ventilation openings. The greater the difference in temperature between the air of the room and the air in the brooder, and the younger the chicks, other things being equal, the smaller the amount of opening required to ventilate the brooder effectively.

If a brooder filled to capacity with newly hatched chicks on the basis of 7 square inches of floor space per chick is operated at a temperature of 95° F in a room whose temperature is 50°, and the only way air can enter and leave is under or through a curtain, a space of 1 inch below the curtain will provide good ventilation. As the chicks grow older they consume increasing amounts of oxygen and give off increasing amounts of carbon dioxide. Less heat, from week to week, however, is needed to make them comfortable.

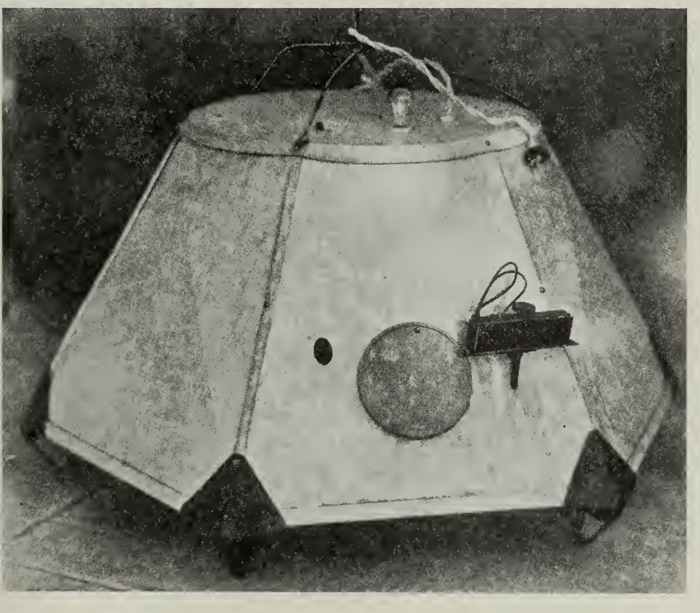

Fig. 9.—A portable, curtainless electric brooder using glowing units and a convex heat reflector like that shown in sketch 16 of figure 3. This brooder has two or more circuits, according to the size. One circuit is operated by the thermostatic breaker and the others by hand switches. Note the steep sides and flat top with pilot light. The top is heavily insulated.

Lowering the temperature of the brooder as the chicks grow reduces the difference in temperature between the brooder and the room, but retards ventilation. To offset this effect and give the chicks the increased ventilation needed, the canopy can be raised higher from the floor. Since few chicks are under the hover at any one time during the day, however, the canopy can be lowered in the morning and ventilation reduced. Then at night it can be raised again to supply the ventilation needed when all the chicks are under the hover. This method of raising and lowering the canopy will conserve electric energy and still provide good ventilation (see fig. 11).

It is not practicable to set the edge of the canopy of a curtainless brooder lower than 3½ or 4 inches above the floor. A curtainless brooder would, therefore, under the brooding conditions described in the previous paragraph, provide excess ventilation, and waste heat.

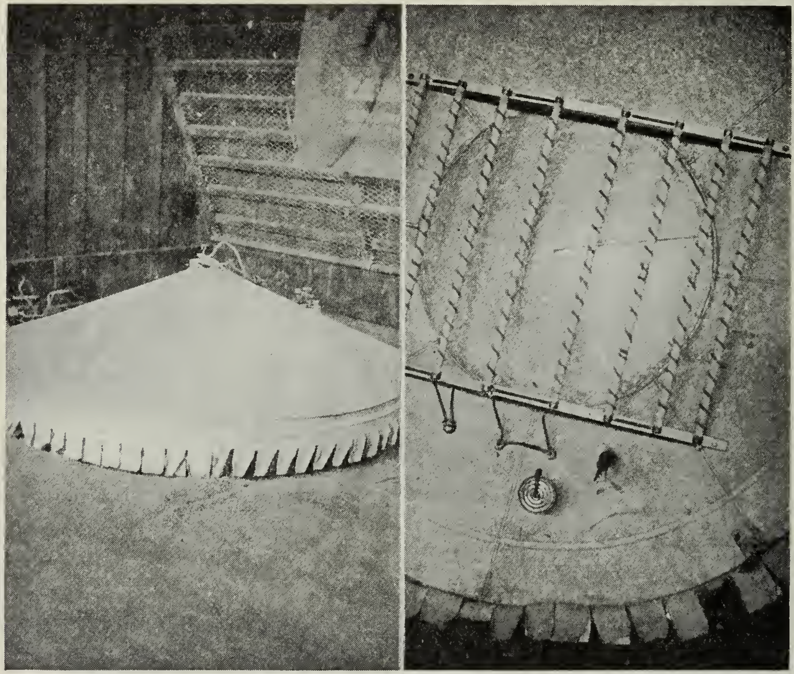

Fig. 10.—Two views of a galvanized-iron, electric brooder, showing low construction of hover and arrangement of overhead non-glowing heating elements. It can be placed under the droppings board and either supported on its own legs or suspended from above. The canopy is so flat that chicks can perch on it. The heating elements are wound on asbestos sticks and are fastened to the hover by spring clips. Should the wire on one stick burn out it is easily removed and a new one snapped into place. Note that two heating circuits are connected in parallel, thus assuring some heat should one circuit burn out. (From Bul. 441.)

On the other hand, when circulation under the canopy is the only means of ventilation, a curtained brooder must be raised successively higher from the floor as the chicks grow or as the weather becomes warmer. Hence, in the warmer weather of spring, or with older chicks, the curtained brooder may use just as much electricity as a curtainless brooder. It is only in cool weather that a low-set, curtain-

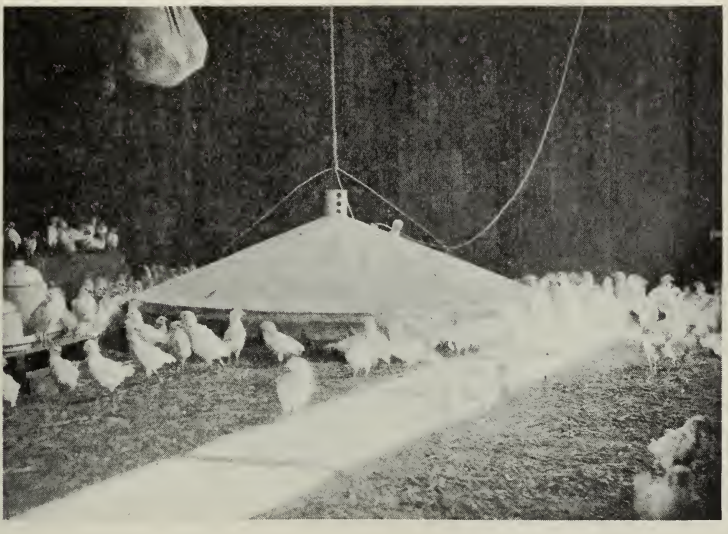

Fig. 11.—A galvanized-iron, electric brooder, using overhead non-glowing elements, and a central ventilating stack. The counter weight at the top of the picture is used to adjust the height of the hover from the floor to regulate ventilation. (From Bul. 441.)

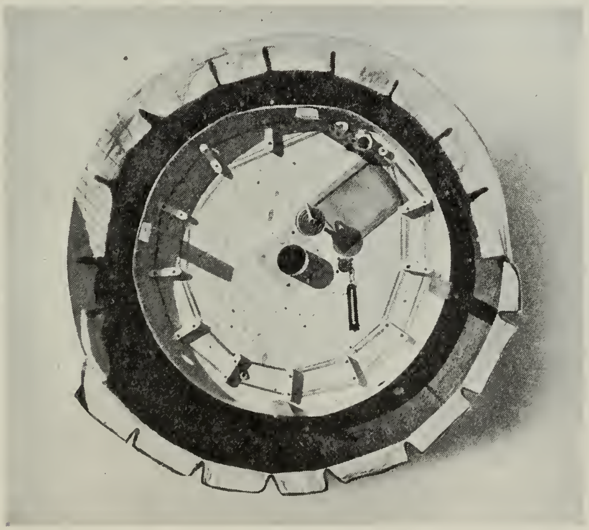

Fig. 12.—Interior view of an electric brooder similar to the one shown in figure 8. This brooder is so wired that the two heating circuits work in parallel at 110 volts and in series at 220 volts. The change is simply made. The hover is well insulated against heat losses, especially in the central section. (From Bul. 441.)

less brooder is particularly handicapped through a lack of such control of ventilation as a curtain provides. A curtain offers a simple, practical means of regulating ventilation but requires careful operation; omitting the curtain assures ventilation that guards the chicks against mistakes of the inexperienced operator, but may materially increase fuel costs.

CONSTRUCTION OF BROODER

Heat Capacity or Connected Load.—An electric brooder requires sufficient heating capacity to keep newly hatched chicks warm under the coldest temperature conditions practicable for the operation of such a brooder (see section "Room Temperature"). This capacity, as expressed in number of watts of connected load, is largely influenced by the total area of the openings through which air can pass in and out. For example, a curtainless brooder 42 inches in diameter with the edge of the canopy 4 inches from the floor would require a heating capacity of not less than 700 watts to insure ample heat for very young chicks in a room temperature of 40° F. Under like conditions a similar brooder with a curtain the bottom of which was only about 1 inch above the floor, would need not more than 400 watts to keep the chicks warm enough (see table 1). This difference in performance is due to the difference in the amount of opening under the canopy for ventilation.

Quality of Insulation.—One very satisfactory method of insulating a metal canopy is to use two cones having the same basal diameter, but different slopes, so that when one is fitted over the other the edges meet and there is a tapering air space from the edges to the points of the cones. This air space is packed with a good insulating material of light weight. Insulation exerts a direct influence on heating capacity and cost of operation, because of its effect on heat loss through conduction. The top of the brooder may get decidedly hot if not well insulated. Unless the job of insulating is well done, it may serve only to increase the cost to both the manufacturer and consumer. A sheet of asbestos pasted to the under side of a metal canopy not only provides little insulation, but is soon picked off by the chicks after the brooder is put into use.

Kind of Heating Units.—In figure 1 a heating unit made of straight wire strung on porcelain knobs is shown. Instead of using knobs, some manufacturers sew the wire in predetermined patterns into a large asbestos pad which is fastened to the under side of

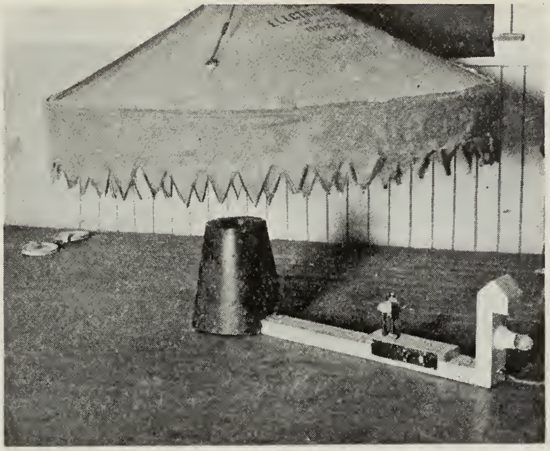

Fig. 13.—A conical, galvanized-iron brooder, with heating elements cased in concrete. The concrete block is hollow at the center and is connected to the room air by an air duct at the bottom. The air in the center of the block becomes heated and rises, and is replaced by fresh air through the duct. (From Bul. 441.)

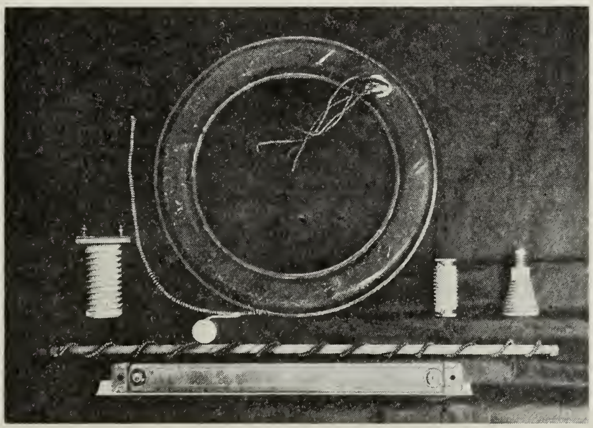

Fig. 14.—Some representative types of heating units used in electric brooders. In the strip heater and ring unit, the resistance wire is enclosed in a metal sheath, and sometimes imbedded in a plaster-like, refractory material, to increase the durability of the unit. Screw-socket heating units that glow are apt to cause trouble if installed with the threaded receptacle above the wire unit, owing to the effect of the intense heat on the receptacle. The unit consisting of a resistance coil wound on a rod is shown installed in figure 10. It is held by brass contact clips and is easily slipped in or out.

the brooder top. In figure 10 the heating wire is first coiled on asbestos-covered sticks with broad copper rings on each end to serve as terminals. The sticks are held in spring clips and are easily removed for repairs or renewal. Figure 12 shows heating units consisting of two strings of coiled resistance wire held in place with porcelain cleats. Figure 5 shows reflectors in which the heating units screw into porcelain lamp sockets. In figure 13 the heating wire is cast in a hollow concrete block to form a massive, heating unit. Other types of units used are strip heaters, and metal-sheathed rings. A variety of heating units is shown in figure 14.

Durability of Heating Elements.—Frequent heating to very high temperatures, oxidation from exposure to the air, and fusing because of short circuits, are the principal causes of deterioration in the resistance wire used for heating units. This deterioration can be retarded and the useful life of the wire materially lengthened by:

1. Distribution of the connected load among the manually and automatically controlled circuits in such a way as to reduce the opening and closing of the thermostatic breaker to a minimum. The less frequently the breaker opens, the less frequently the heating units in the circuit will be heated and cooled, as pointed out in the discussion of multiple circuits and the distribution of the load.
2. The use of heating units in which the wire does not attain a temperature higher than 932 degrees (see table 2).
3. Proper support of the resistance wire to prevent short circuits due to the lengthening that occurs when it is heated. The runs in straight or coiled open wiring should not be close enough to entail the risk of touching when heated, and should be supported at least every 12 inches.
4. The use of terminals to the heating units which are of good size, have screw connections and are strongly made. Solder joints and screw connections made of too light material are a fertile source of trouble.

Number of Circuits and Distribution of Connected Load.—Multiple circuits provide a better method of safeguarding chicks against chilling due to accidental breaks in the heating system than does a single circuit (see fig. 12). If the thermostat controls only one circuit, the failure of this circuit with the hand switches open would result in the complete stoppage of heat production. Such failure would be particularly serious at night. With two circuits on the breaker, the second one would continue to function and provide sufficient heat to prevent serious injury to the chicks until better provision could be made for them.

If part of the heat is controlled by one or more snap switches and part by the thermostatic breaker, the total load should be so divided between the automatically and manually controlled circuits that the desired temperature can be readily maintained at all times. The use of the dual heat control, especially in brooders with a connected load exceeding 500 or 600 watts, also reduces the current passing through the automatic breaker and minimizes burning and pitting of breaker points. To cite an extreme case, a certain manufactured brooder was so wired that a heating load of 1,200 watts operated continuously so long as the brooder was connected to the line, and a load of only 300 watts was controlled by the thermostatic breaker. A better method would be to place 500 watts in two circuits on the automatic breaker, 400 watts on one snap switch and the balance of 600 on another. This would provide much more effective temperature regulation and materially reduce operating costs under most conditions.

All of the connected load should be under the control of automatic or manual switches. One automatic breaker is sufficient but enough manual switches should be provided to maintain the desired temperature with a minimum opening of the automatic breaker circuit.

Sensitivity and Dependability of Automatic Breaker.—The maintenance of the desired temperature conditions in the brooder depends upon the accuracy with which the thermostat switch functions, and such accuracy in turn depends upon correct design and construction. Silver contacts do not stick or cause trouble from burning if cleaned and trued up occasionally. Very small contacts are damaged more from arcing than larger ones; whereas the upturned surface of a very large lower contact may catch fine particles of dirt or sand that will hold the contacts apart. Contacts ⅛ to $\frac{3}{16}$ inch in diameter have proved satisfactory.

The sensitiveness of a thermostat switch depends on the length of the breaker arm in the bimetallic type, and on both the length of the arm and the number of cells in the wafer type. The longer the arm, or the greater the number of cells in the wafer, the smaller is the rise in temperature above the normal required to open the points of the breaker. Hence, when the movement of the wafer is combined with that of the lever arm, the arm can be shortened. The entire breaker is thus made much more compact and is still kept sensitive enough for the purpose. The cost of a wafer increases with the increase in number of cells. A compact breaker with enough cells to prevent more than deviation of ½ degree may be desirable in an incubator, but in a brooder a 2 to 3-degree variation is not objectionable, so that a less costly two-cell wafer can be used satisfactorily. The breaker, as a whole, should be simple and sturdy in design, have a minimum of play at the pivotal points, and be easy to repair.

Fuse Protection.—Another feature which adds to the reliability of electric brooders is proper fusing. The main circuits to which brooders are connected are usually properly fused, but the individual brooders rarely are. A broken heating coil falling on a damp concrete floor or otherwise causing a short-circuit might blow a main fuse and thus interrupt the service to a number of brooders. A separate fuse of the proper size on each brooder would guard against service interruption to more than one brooder from any cause within the brooder itself. A simple method is to place a porcelain receptacle in one side of the line and screw in a fuse plug. The fuse plug will also serve as a cut-out.

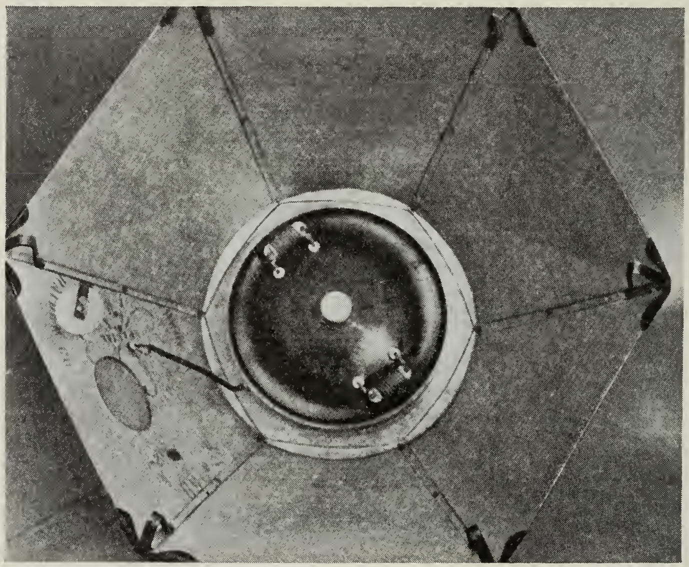

Fig. 15.—Interior of brooder shown in figure 9. Note attraction light, ether wafer, spun-brass reflector, and heating units with heavy, bolted terminals. Deep grooves in the heating units hold the wire more firmly in place than shallow grooves when it expands on heating.

Pilot Lights.—A pilot light is useful in showing that the circuit to which it is connected is functioning (see figs. 8, 9). It makes for convenience in that it is so readily observed. The ideal arrangement would be to have a pilot lamp in each circuit, but this would increase the cost of brooders having a number of circuits. The hand-operated circuits are less frequently in use and therefore less subject to operating trouble than those automatically controlled; hence, there is a greater need for pilot lamps on the breaker circuits.

Attraction Lights.—An attraction light in the brooder has been found of considerable value in teaching chicks to use the hover and not stray away into cold corners (see fig. 15). It materially reduces the labor of getting the chicks properly settled under and around the hover at night. The operator can reach into the hover and screw such a bulb in or out of the socket to turn the light on or off, but a snap switch is more convenient. A dim, blue light is satisfactory, and it need be no larger than 10 watts.

Methods of Adjusting Height of Brooder.—As previously pointed out in discussing the curtain, it is desirable to regulate the height of a portable electric brooder from the floor. With many of the brooders now on the market this is accomplished by suspending the brooder from one end of a rope running through a ceiling pulley and a counterpoise weight from the other (fig. 11). A sack of sand makes an excellent counterpoise weight. Legs are also provided on nearly all brooders. They are very convenient in fixing a definite minimum height. In a warm room the brooder should be raised higher than in a cool room to obtain the same amount of ventilation under the curtain. If the legs are adjustable for length, they will serve to regulate the height of the brooder to a certain extent and postpone the time when rope and pulley are needed.

Type of Thermometer and Its Location.—One of the most irritating defects found in many electric brooders is an inaccurate thermometer. Any cheap thermometer will not do. It should be made especially for brooder use; should be accurately graduated; and be of convenient size and shape. In some thermometers the top of the glass tube is finished without projections, whereas incubator thermometers are sealed at the top with a pointed projection at a right angle to the glass tube. This projection fits into a hole in the metal back and so prevents the tube from shifting on the scale. In the cheap brooder thermometer without this pointed projection, the glass tube soon gets loose and slides up and down with handling so that it may give a reading as much as 10° above or below the correct temperature (see fig. 16).

A very convenient way to place the thermometer is to suspend it through a hole in the top of the brooder so that it can be easily withdrawn from the outside. This hole should be near the outer edge of the top. A convenient thermometer mounting consists of a cylindrical piece of wood about one inch in diameter with the metal-backed thermometer set into the side of it. This wooden holder should be long enough to bring the thermometer bulb to within 2 inches of the floor, and to project about 2 inches above the hole in the brooder top to form a handle. A thin metal washer can be slipped over the handle and be fastened to the wood at the proper height to hold the thermometer in position and to seal the hole.

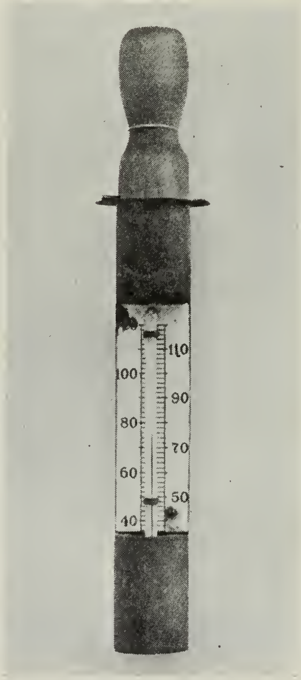

Fig. 16.—An excellent type of brooder thermometer. It is designed for insertion through a hole in the top or side of the brooder so that it can be conveniently reached and read. It should be of such length and so placed that the thermometer bulb is 2 inches above the floor and within 5 inches of the outer edge of the canopy.

Shape of Canopy.—The shape of the canopy, or brooder top, affects its cleanliness. Chicks cannot perch on a steeply sloping canopy, whereas one flat enough for them to walk on becomes soiled with droppings and must be cleaned frequently (see figs. 9, 10, 17). It is more difficult, however, to build a steeply sloping top on a wooden brooder than it is to make it flat.

Durability of Construction.—A brooder receives more or less hard service. If permanently built-in, it does not suffer the wear and tear of being moved from place to place, but the usage received from day to day in brooding with any kind of brooder is such that strong, durable construction pays. A well designed and constructed electric brooder may cost more to buy but will cost less per year for dependable and satisfactory service. Flimsy legs, a thin sheet iron canopy that twists and weaves when moved, very light bracket supports for the thermostatic breaker, and poorly constructed heating units increase depreciation and repairs and decrease operating efficiency.

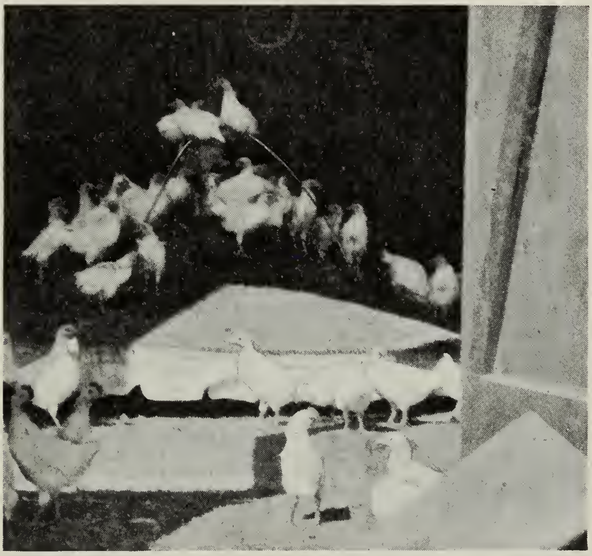

Fig. 17.—Chicks will perch on and soil the top of a brooder that is not steep enough to prevent their standing on it.

DETERMINING THE HEATING SPECIFICATIONS FOR AN ELECTRIC BROODER

Heat Requirement.—Under ordinary operating conditions a curtain-type brooder will require approximately 1.5 to 2.0 watts of heating capacity per chick and a curtainless brooder will need 2.5 to 3.5 watts per chick (see table 1). The higher values are required when brooding is done in cold brooder rooms without the use of auxiliary heat to take the chill from the room, and in small brooders where the number of chicks is small and the space under the edge of the canopy through which heat can escape is greater in proportion to its floor area than it is in larger brooders.

The heating elements of a brooder with a capacity of 300 chicks would, therefore, have a total rating, according to table 1, of: 450 to 600 watts for the curtained brooder, and 750 to 900 watts for the curtainless brooder.

The heating elements can be of any suitable type as explained in the section describing different kinds of heating units.

TABLE 1

PRINCIPAL SPECIFICATIONS FOR ELECTRIC BROODERS TO OPERATE IN ROOM TEMPERATURES ABOVE 40° F

Capacity		Area square inches	Diameter if circular, inches	Side if square, inches	Heat capacity or connected load, watts		Electricity required to brood chicks to 6 weeks, kilowatt-hours	
Chicks	Turkey poults*				Curtained	Curtainless	Curtained	Curtainless
100	50	700	30	27	150- 200	250- 350	50-100	100- 200
200	100	1,400	42	37	300- 400	500- 700	100-200	200- 400
300	....	2,100	52	46	450- 600	750- 900	150-300	300- 600
462	....	3,216	64	57	700- 925	1,100-1,350	225-450	500- 900
582	....	4,072	72	64	875-1,164	1,350-1,700	300-600	600-1,100

* It is not advisable to brood turkeys in groups of more than 100.

Size and Length of Resistance Wire.—Let us assume that the curtained brooder is to have a total heating capacity of 600 watts in two circuits of 300 watts each, and the curtainless brooder a capacity of 900 watts in two circuits of 450 watts each. Then, the current in amperes and the total resistance of the heating system in ohms must be determined from the following formulas, volts and watts being known:

Using a current with a voltage of 110, and since amperes $= \frac{\text{watts}}{\text{volts}}$,

$$\text{then } \frac{300}{110} = 2.73 \text{ amperes, for the curtained brooder;}$$

$$\text{or } \frac{450}{110} = 4.09 \text{ amperes, for the curtainless brooder.}$$

Using these two values the total resistance of each circuit is found as follows: since ohms $= \frac{\text{volts}}{\text{amperes}}$, then

$$\frac{110}{2.73} = 40.3 \text{ ohms, for the curtained brooder;}$$

$$\text{or } \frac{110}{4.09} = 26.9 \text{ ohms, for the curtainless brooder.}$$

The person constructing the brooder must also decide if the elements are to operate at a glowing or non-glowing temperature (see section "Durability of Heating Elements"). If they are to glow, the degree of glow must be decided. Resistance wire assumes colors with corresponding temperatures as indicated below:

Color of wire	Temperature, degrees Fahrenheit
Black or natural	0 to 800
Faint red	800 to 1,050
Blood red	1,050 to 1,150
Cherry red	1,150 to 1,300
Bright red	1,300 to 1,600

It is here assumed that the curtained brooder will use "black" heat with a wire surface temperature of 572° F and the curtainless brooder will have glowing or faint red heating units with a wire surface temperature of 932°.

TABLE 2*

RESISTANCE, CURRENT, AND TEMPERATURE CHARACTERISTICS OF "NICHROME IV" RESISTANCE WIRE, WITH SPECIFIC RESISTANCE OF 650 OHMS PER CIRCULAR MIL FOOT AT 68° F

Wire size, B. & S. gauge	Diameter of wire, inches	Resistance in ohms per foot at 68°F	Amperes necessary to produce temperatures listed below								
			392° F	572° F	752° F	932° F	1,112° F	1,292° F	1,472° F	1,652° F	1,832° F
10	0.102	0.0624	19.5	25.4	30.9	37.1	43.7	51.0	57.7	65.6	74.4
11	0.091	0.0784	16.5	21.5	26.1	31.4	36.9	43.0	48.6	55.3	62.6
12	0.081	0.0990	14.0	18.2	22.1	26.6	31.3	36.5	41.3	47.0	53.2
13	0.072	0.1253	11.8	15.3	18.2	22.5	26.5	30.9	35.0	39.8	45.0
14	0.064	0.1586	10.0	13.0	15.9	19.0	22.5	26.1	29.6	33.7	38.1
15	0.057	0.2000	8.50	11.1	13.5	16.2	19.0	22.2	25.1	28.5	32.3
16	0.051	0.2499	7.20	9.40	11.4	13.7	16.2	18.8	21.4	24.3	27.5
17	0.045	0.3209	6.10	7.95	9.65	11.6	13.7	15.9	18.1	20.5	23.2
18	0.040	0.4062	5.18	6.73	8.20	9.85	11.6	13.5	15.3	17.4	19.7
19	0.036	0.5015	4.37	5.70	6.95	8.35	9.85	11.4	12.9	14.7	16.7
20	0.032	0.6347	3.70	4.80	5.85	7.05	8.30	9.70	10.9	12.4	14.1
21	0.0285	0.8002	3.13	4.07	4.95	5.95	7.05	8.15	9.25	10.5	11.9
22	0.0253	1.015	2.65	3.45	4.20	5.05	5.95	6.95	7.85	8.90	10.1
23	0.0226	1.272	2.26	2.84	3.57	4.30	5.06	5.90	6.67	7.60	8.60
24	0.020	1.625	1.91	2.48	3.02	3.64	4.27	4.97	5.63	6.40	7.25
25	0.0179	2.028	1.62	2.10	2.55	3.08	3.64	4.23	4.80	5.45	6.13
26	0.0159	2.571	1.37	1.78	2.17	2.60	3.07	3.57	4.05	4.60	5.20
27	0.0142	3.223	1.16	1.51	1.84	2.21	2.61	3.04	3.44	3.90	4.42
28	0.0126	4.094	1.00	1.29	1.58	1.89	2.23	2.60	2.94	3.35	3.89
29	0.0113	5.090	0.86	1.11	1.35	1.62	1.92	2.23	2.52	2.95	3.25
30	0.010	6.500	0.73	0.95	1.17	1.40	1.65	1.92	2.17	2.47	2.80
31	0.0089	8.206	0.63	0.82	1.00	1.20	1.41	1.65	1.86	2.12	2.40
32	0.008	10.15	0.54	0.70	0.86	1.03	1.21	1.42	1.60	1.82	2.06
33	0.0071	12.89	0.46	0.60	0.74	0.88	1.04	1.21	1.37	1.56	1.77
34	0.0063	16.37	0.40	0.52	0.63	0.77	0.90	1.04	1.18	1.34	1.52
35	0.0056	20.72	0.34	0.45	0.54	0.65	0.77	0.89	1.01	1.15	1.30
36	0.005	26.00	0.29	0.38	0.47	0.56	0.66	0.77	0.87	0.99	1.12
37	0.0045	32.09	0.25	0.33	0.40	0.48	0.57	0.66	0.75	0.85	0.96
38	0.004	40.62	0.21	0.28	0.34	0.41	0.49	0.57	0.64	0.73	0.82
39	0.0035	53.06	0.18	0.24	0.29	0.35	0.41	0.49	0.54	0.62	0.70
40	0.0031	67.63	0.16	0.20	0.25	0.30	0.35	0.41	0.46	0.53	0.60

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* Adapted from tables by Driver-Harris Company, Detroit, Michigan. Similar tables can be obtained from the manufacturers for other makes or grades of resistance wire. The data are for straight wire in air, in a horizontal position.

Reference is now made to table 2 in order to find what size of wire will carry 2.73 amperes at a surface temperature of 572° F and 4.09 amperes at 932° respectively. Opposite wire number 23 under the column headed 572° appears 2.84 amperes and under the column headed 932° appears 4.30 amperes, so that No. 23 wire will do for both cases. The length of this wire must be such as to give a total resistance of 40.3 ohms for the curtained brooder and 26.9 ohms for the curtainless brooder, as determined above. The resistance per foot for each wire is given in column 3, table 2, but must be corrected as shown below because the resistance changes as the wire heats.

Temperature, wire surface, degrees Fahrenheit	Correction factor[5]
68	1.0000
212	1.0051
392	1.0250
572	1.0400
752	1.0490
932	1.0530
1,112	1.0480
1,292	1.0440
1,472	1.0460
1,652	1.0550

Using the correction multiplier of 1.04 for 572° and 1.053 for 932°, it is found that No. 23 wire has a resistance of 1.272 × 1.04 or 1.323 ohms per foot at 572° and 1.272 × 1.053 or 1.34 ohms at 932°. The length required is then found by dividing the corrected resistance per foot into the total resistance, viz.:

$40.3 \div 1.323 = 30.5$ feet of No. 23 wire for the curtained brooder, and

$26.9 \div 1.34 = 20.1$ feet of No. 23 wire for the curtainless brooder.

The complete information needed to construct a 300-chick capacity curtained brooder to operate at black heat on a 110-volt circuit and a curtainless brooder at 300-chick capacity to operate at a glowing wire temperature of 932° F is assembled in table 3.

The length of wire can also be obtained directly from the chart in figure 18. The intersection of the horizontal lines corresponding to 300 watts with the curve for No. 23 wire gives the length, as shown by the vertical lines, of about 30.6 feet at a temperature between 392° and 540° F. That for 450 watts gives an approximate length of 20.1 feet for No. 23 wire for a temperature a little less than 932° F.

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[5] Adapted from tables published by the Driver-Harris Company of Detroit for Nichrome resistance wire with a specific resistance of 650 ohms per circular mil foot at 68° F.

TABLE 3

Specifications for Brooders of 300-Chick Capacity as Computed from Tables

Kind of brooder	Diameter of brooder, inches	Number of circuits	Wattage per circuit required	Current in circuit, amperes	Wire temperature	Size of wire B. & S.	Length of wire per circuit, feet	Fuse required, amperes
Curtain, non-glow	52	2	300	2.73	572° F	23	30.5	10
Curtainless, glowing	52	2	450	4 09	932° F	23	20.1	10

OPERATING AN ELECTRIC BROODER

Ventilation and Humidity.—The air breathed in by the chick is warmed and brought into intimate contact with the mucous lining of the air passages, while oxygen is being taken from it. When exhaled, it not only contains carbon dioxide but is also heavily charged with water vapor. The fresh droppings, as they dry, also contribute to the moisture content of the air. When the chicks are in the brooder they are therefore constantly producing moisture which must be removed by ventilation.

The quantity of water in the form of vapor that air will hold per unit volume is doubled with a rise in temperature of 22° to 25° F, and is halved with a similar fall in temperature, within the range met with in brooding chicks. For example, every cubic foot of air at a room temperature of 60° F entering an electric brooder at an automatically maintained temperature of 85°, even though saturated when it enters, can, when heated to the hover temperature, absorb approximately 100 per cent more moisture than it contained when it entered. It can absorb more than this amount if its relative humidity, when it enters the brooder, is below 100 per cent. Condensation of moisture in an electric brooder (which is commonly called "sweating") occurs only when the moisture given off by the chicks is in excess of what the air will take up and remove. The rate at which the moisture is removed, however, depends on the rate at which the air passes through the brooder.

The need for fresh air increases as the chicks grow, whereas, the need for artificial heat decreases. Therefore, the ventilation openings should be enlarged from week to week to produce a sufficient flow of air through the brooder to meet the growing needs of the chicks and keep the hover dry. Probably the most practical means of accomplishing this is by diffusion through and under a curtain. The effectiveness of this method of ventilation will depend largely upon the height of the curtain above the floor in relation to (1) the number of chicks under the hover contaminating the air, (2) the size of these chicks, and (3) the difference in temperature between room and brooder. In a detailed study[6] at this Station of the relation of ventilation in an electric brooder to the health and growth of chicks, as little as 2 cubic feet per minute per 100 chicks proved as satisfactory, up to 6 weeks of age, as larger amounts. Dampness under the hover, even though slight, is evidence of the need for increased ventilation.

Brooder Temperature.—A brooder is heated to make chicks in it comfortably warm. Therefore the actions of the chicks are the most important indication of proper temperature conditions. When chicks crowd together they are cold. They spread out when they are comfortable. A reading of 95° F with the thermometer bulb 2 inches above the floor and 5 inches in from the outer edge of the hover will usually be found satisfactory for baby chicks until they are a week old. Then the temperature should be gradually lowered at the rate of about 4 degrees a week till artificial heat is no longer required.

Room Temperature.—Newly hatched chicks must not only be kept warm and comfortable but they must be taught to eat. If the room is too cold the chicks will ''hug the hover'' and not come out. Oil, gas, and coal-heated brooders exert more of an effect on the temperature of the room than do those using electricity; and curtained brooders have less effect than those without curtains.

In electric brooders with attraction lights, the water jars and feed receptacles can be placed inside or partly inside the hover for the first few days provided it is not loaded too heavily with chicks. Another method which helps to overcome the handicaps of a cold room while the chicks are being taught to eat and are gaining the strength to cope with cool temperatures, is to use a tight fence instead of one of open construction around the brooder to keep the chicks from straying into cold corners and getting chilled before they have learned to return to the hover for warmth. If made of such material as burlap-covered netting, roofing paper, or sheet metal, and placed about a foot away, this fence will sufficiently retard the dissipation of the warm air escaping under the canopy to materially raise the temperature of the small feeding space thus provided. It may be necessary temporarily to raise a curtained brooder higher than is required for good ventilation in order to have enough heat escape through the curtain. A third method is to place a temporary enclosure around the brooder for the first week. If a laying house is used for brooding, such an enclosure is readily made by placing the brooder under the droppings board in one corner of the room and using light panels of transparent or translucent material to enclose a space 2 to 3 feet larger than the brooder itself. In very cold weather a small, electric room heater can, if necessary, be used to supplement the brooder in warming this enclosure during the day when the chicks are feeding.

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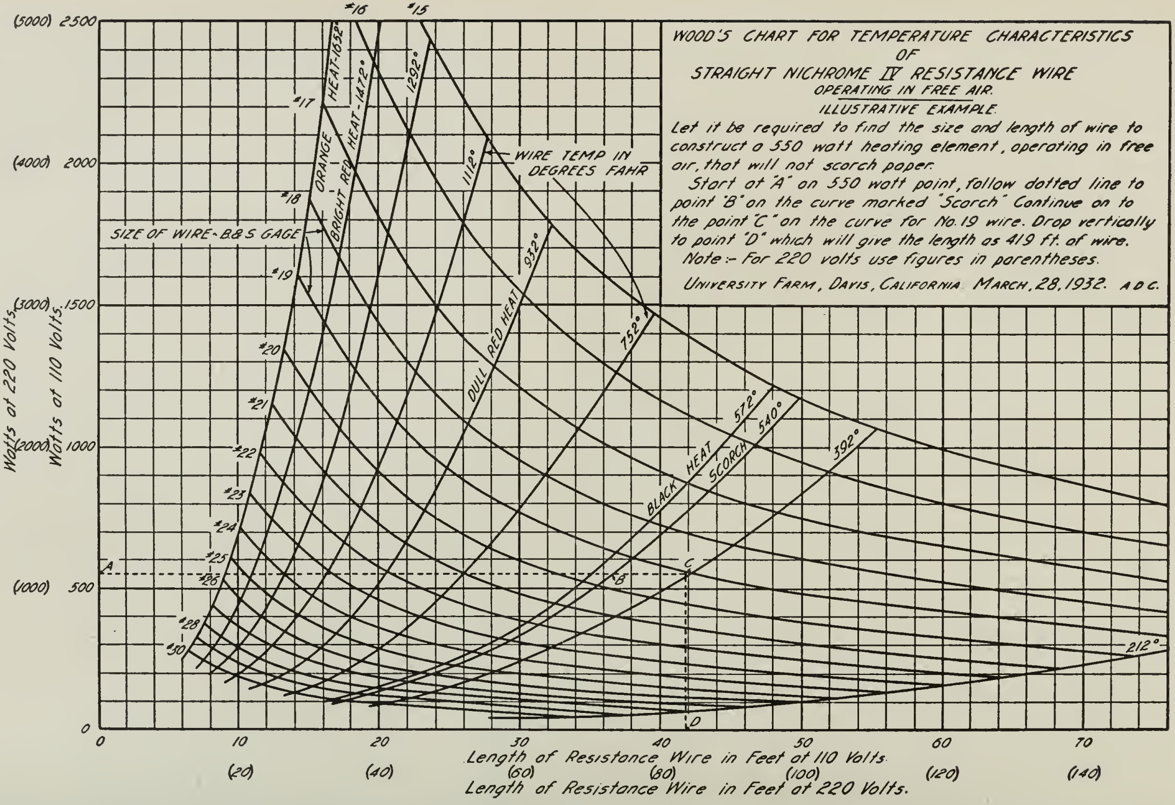
[6] Unpublished data.

It will be found advisable, however, to use auxiliary heat to warm the room if much cold weather brooding is to be done with electric brooders. For the first week after the chicks are put in the brooder, a room temperature of not less than 50° F during the day is desirable. Rooms with tight walls and ceiling can be more easily heated than unceiled rooms with wire partitions. Furthermore, it is necessary to heat only the particular ceiled room or rooms being used, whereas, in an open brooder house with many pens, to warm the air of any one pen it would be necessary to heat the entire house. Ceiled rooms therefore permit a more economical use of heat to warm them for cold-weather brooding, when only a portion of a long brooder house is used at a time.

Servicing the Brooder.—In getting an electric brooder ready to receive chicks, it should be set up in the brooder room and carefully inspected. If the thermostat is of the ether wafer type, the wafer should be removed and tested. It is advisable to keep an extra ether wafer on hand to replace the one in the brooder should that one give out during a brooding period. A magneto file and a few short ⅛-inch brass bolts with double brass or copper washers should also be kept on hand. The file is needed to clean and square the breaker points. Corroded points may reduce or stop the flow of current. The bolts are used to repair any break that may occur in the wire of the heating units. Twisting the broken ends of the wire around the bolt between the two washers and then screwing the nut on very tightly so that the wires are held in firm contact will give a tight connection that should hold up a long time in brooders using black heat. In the case of a glowing element a break anywhere but at the ends of the wire can best be remedied by replacing the element, as repaired breaks usually do not last long. If the break is at either end of the wire where it is connected to a binding post, a new connection can generally be made. After the brooder has been checked over



WOOD'S CHART FOR TEMPERATURE CHARACTERISTICS
OF
STRAIGHT NICHROME IV RESISTANCE WIRE
OPERATING IN FREE AIR.
ILLUSTRATIVE EXAMPLE.

Let it be required to find the size and length of wire to construct a 550 watt heating element, operating in free air, that will not scorch paper.

Start at "A" on 550 watt point, follow dotted line to point "B" on the curve marked "Scorch" Continue on to the point "C" on the curve for No. 19 wire. Drop vertically to point "D" which will give the length as 41.9 ft. of wire.

Note:- For 220 volts use figures in parentheses.

UNIVERSITY FARM, DAVIS, CALIFORNIA MARCH, 28, 1932. A D C.

Fig. 18.—Chart for determining the size and length of resistance wire required for heating units of any specified wattage and operating temperature.

and any necessary repairs and adjustments made, it should be operated for a day or more to set the thermostat to the correct temperature for the chicks and to be sure that the heating system is functioning satisfactorily.

BROODING TURKEYS, DUCKS, AND GAME FOWLS ELECTRICALLY

Young turkeys, ducks, pheasants, quail, etc. can be brooded under electric brooders just as successfully as young chickens, provided the rearing methods used are adapted to the peculiarities of the particular species being reared. Game birds do best when brooded in small groups (see fig. 19). For this reason brooders 36 inches or less in diameter are most commonly used. Most satisfactory results are obtained with turkey poults when not more than 100 are brooded together under one hover and, as previously mentioned, a floor space of 14 square inches per poult is provided. Ducks also thrive better when brooded in groups of 100 or less and are allowed a floor space similar to that for turkey poults.

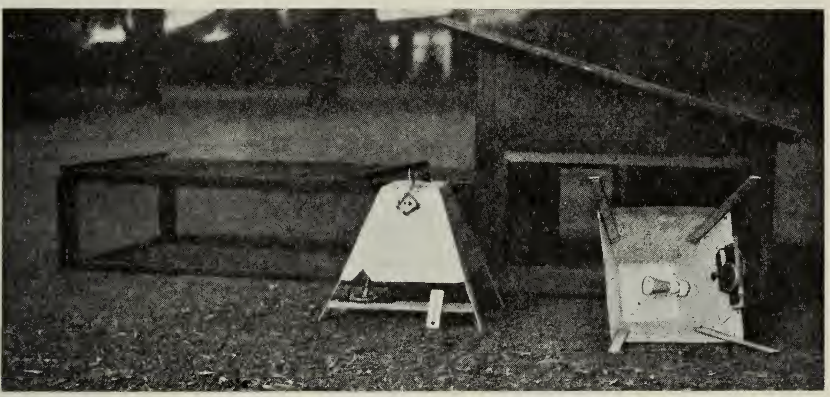


Fig. 19.—Specially designed, electric brooders used to brood small lots of pheasants, quail, and other game birds. The brooder room and run are shown in the background.

SAFETY PRECAUTIONS

In working with any electrical circuit, it is well to remember the following:

One should never attempt to work with a "hot" or live circuit. The circuit switch should first be opened and the circuit fuses removed. While 110 volts will usually not injure one, there are conditions under which it may be dangerous.

All electric wires should be considered ''hot'' until one knows definitely that the circuit is open.

One should never work with a power circuit when standing on wet ground or wet floors.

One should always remember that both legs of an alternating current circuit, as usually operated, are live.

Both legs of each circuit should be fused for about 125 per cent of full load.

Knife switches, except in safety boxes, and bare wires are unsafe.

For further details relating to the installation of electrical wiring and apparatus, the reader is referred to the Electrical Safety Orders issued by the Department of Industrial Relations and Division of Industrial Accidents and Safety, State of California.

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